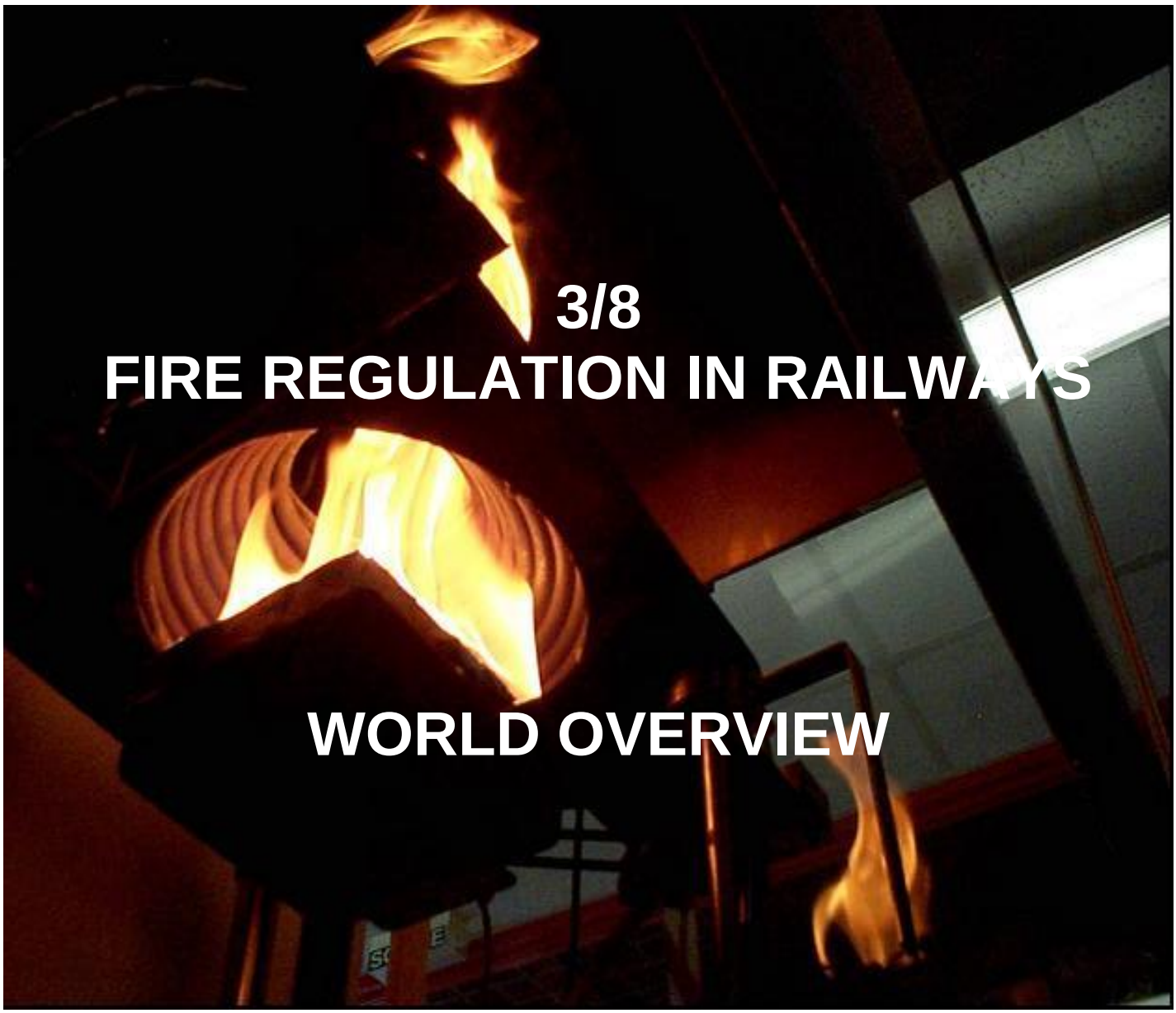

3/8
FIRE REGULATION IN RAILWAYS

WORLD OVERVIEW

CONTENTS

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1 FRANCE

The actual classification used by French regulations for the classification of fire behaviour of materials/component is described in:

- NF F 16-101: ñRolling stock ï Fire behaviour ï Materials selectionò[87]
- NF F 16-102: ñ Rolling stock ï Fire behaviour ï Materials selection ï Application for electrical equipmentò [88]

This classification regards substantially three vehicles categories:

- √ A1: all rolling rock, including their driversôcabins, which travel ferequently though tunnels
- √ A2: urban and suburban rolling rocks which travel infrequently through tunnels,
- √ B: mainline rolling rock, including locomotives, which travel infrequently through tunnels.

Theses standards provide the classification of the material by ñreaction to fireò and ñsmokeò (combination of smoke opacity and toxicity). The product of the above parameters gives the ñrisk index».

1.1 Reaction to fire test

-For wide specimens, the ñreaction to fireò tests classify the material/product into one of six categories: from M0 to M5 and are obtained from combination of the parameters measured. Theses reaction to fire tests comes form the buildings standards

The principal test used in this standard is the ñEpiradiateurò According to NF P 92501 [90] both for rigid and flexible materials more than 5 mm thickness are evaluated. NF P 92503 [91] is used for flexible materials with thickness up to 5 mm. If dripping is noted in the above tests, NF P 92504 [92] and NF P 92505 [93] test s (rate of flame speed) are used.

A complementary test for floor covering is the radiant panel test NF P 92506 [94] which is used only if in the primary test (NF P 92501 and NFP 92503) the material does not obtain the M1 or M2 classification. The NF P 92510 test (calorific potential [95]l) is used to give materials classified in M1 class (below NF P 92501) the M0 class (if the heat of combustion is less than 2500 kJ/kg).

-For small specimens which are not able to be assessed with the M rating,, two tests are used: Oxygen index (NF EN ISO 4589-2 [96]) and glow wire test (NF EN 60695-2-10 [81]). These tests classify the materials into five classes: from I0 to NC (I5). The same tests are used for the electrical materials as described in NF F 16 102.

Table 1: small specimens reaction classes

• Class	Result of test	
	LOI	Glow wire
I0	>= 70	No ignition at 960° C
I1	>= 45	No ignition at 960° C
I2	>= 32	No ignition at 850° C
I3	>= 28	Ignition does not persist at 850° C after glow wire is withdrawn
I4	>= 20	
NC	< 20	Non classified

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-For wires

The wires are assessed according to the NF C 32-070 [119] standard testy method based on the horizontal flame spread along a wire.

1.2 Smoke parameters

Concerning ñsmokeò parameter, as described in the standard, this is obtained from the combination of ñsmoke emissionòand ñtoxicity indexò

The first one is evaluated by the NF X 10 702 (Smoke Density Chamber [97]) and the second one with NF X 70-100 [68]. The Assessment of smoke toxicity is focused on CO, CO_2, HCl, HBr, HF, HCN, and SO_2. The NO_x,, acrolein and formaldehyde derivatives will be probably integrated in the requirements in a near future. The toxic analysis can be realised with the ionic chromatography (Figure 2).

Each of the gas concentrations is divided by an ï acceptable- value and then summed to determine the toxicity index called ITC according to the below formula

$$\mathbf{ITC : 100 \times \Sigma (ti/Cci)} \qquad (3)$$

Table 2: reference value of gaseous species

Gaseous species	CCi mg/m^3
CO	1750
CO_2	90 000
HCl	150
HBr	170
HCN	55
HF	17
SO_2	260
CCi : reference value	

The smoke emission index is a combination of the maximum optical density (Dm) and the summation of optical density up to 4 min VOF4. These two parameters Dm and VOF4 are assessed during the smoke chamber test.

The toxicity results are combined with the smoke emission results. And, at least, these three indices are added to form a smoke index: according to the formula 4:

$$\mathbf{IF = Dm/100 + VOF/30 + ITC/2} \qquad (4)$$

According to NF 16101, the combination of these two parameters gives the ñsmoke valueò with classes from F0 to F5.

Table 3: F rating according IF values

IF value	F rating
<5	F0
< 20	F1
< 40	F2
< 80	F3
< 120	F4
>120	F5

The Smoke Density Chamber (ASTM E 662 in USA [34]) illustrated in is used widely in testing of transportation.

This apparatus measures smoke generation from small, solid specimens exposed to a radiant flux level of 25 kW/m^2 in a flaming (piloted ignition) or non-flaming mode. The smoke produced by the burning specimen in the chamber is measured by a light source ï photometer combination. The attenuation of the light beam by the smoke is a measure of the optical density or quantity of smokeôthat a material will generate under the given conditions of the test.

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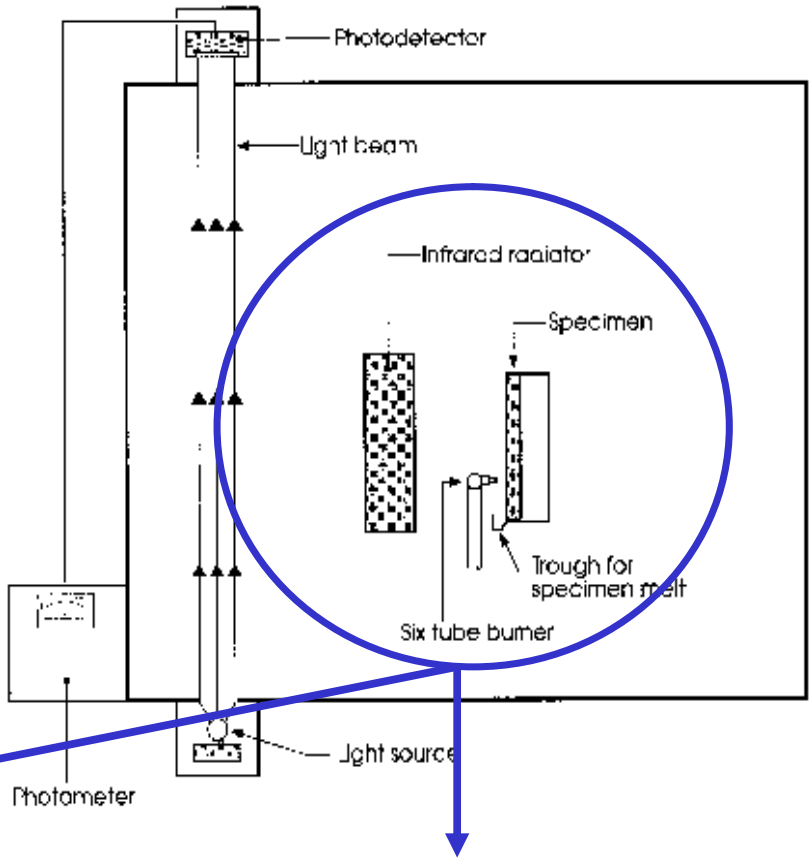
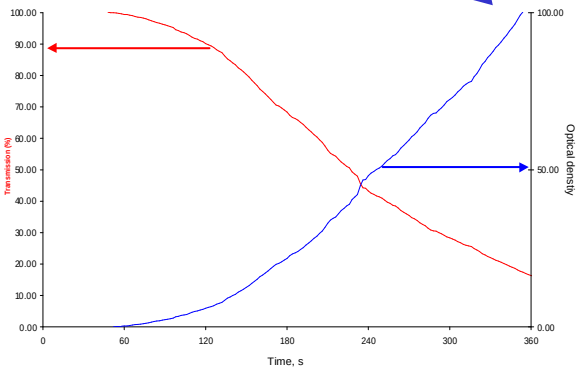
Figure 1: the NF X 10-702 smoke box apparatus (USA : ASTM E 662)





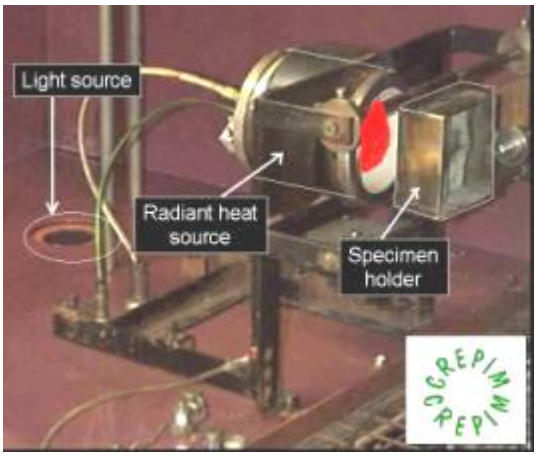


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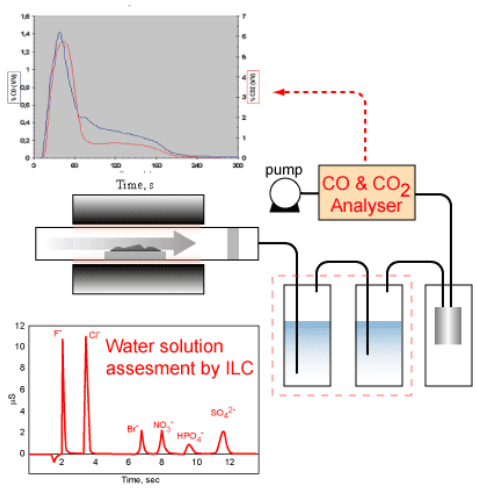
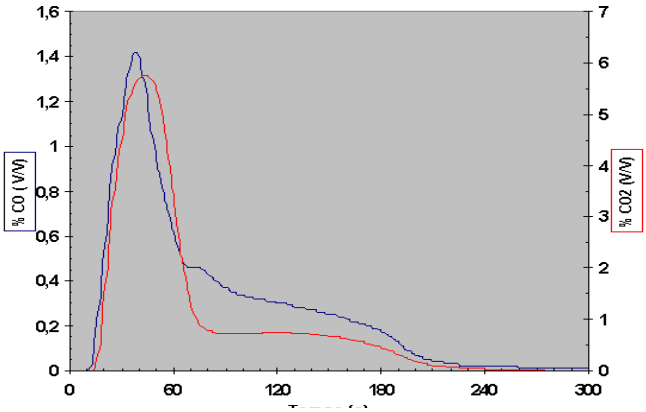
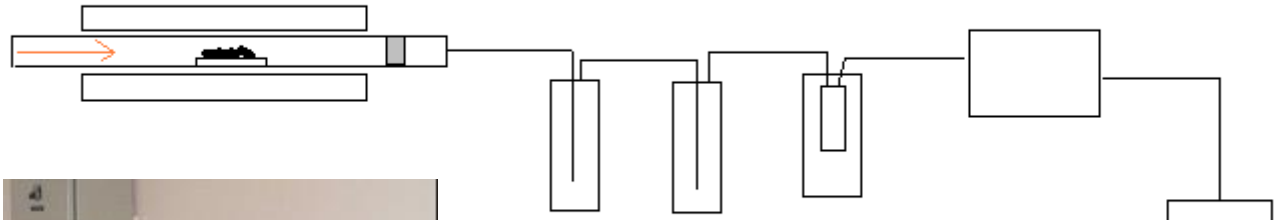
Figure 2: the NF X 70-100 tubular furnace test method



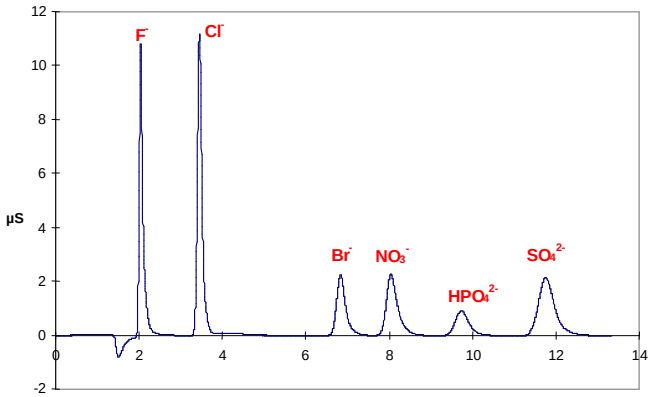


CO and C0$_2$ analyser



Water solutions assessment by ILC

pump



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The French standard gives a complete set of allowable pass criteria by using 18 matrices. Each grid is available for a specific material/component with three classes:

- ✓ Acceptable,
- ✓ Acceptable with agreement of user,
- ✓ Not acceptable.

In general, the higher the F category, the lower the limit on flammability which is allowed.

Figure 3: M and F requirements versus category

	A1	A2	B
Ceiling	M0F0	M0F0	M1F1
Wall	M1F1	M1F1	M2F1
Curtain	M1F1	M1F1	M1F1
Light	M1F1	M1F1	M1F2
Seat (each component)	M1F1	M1F1	M1F2
Flooring	M1F1	M2F1	M2F1
Interior Wires	AF1	AF1	BF2
Exterior Wires	BF1	BF2	CF3
Exterior material	M2F1	M2F2	M3F3
Bed furniture	M1F1	M1F1	M1F1

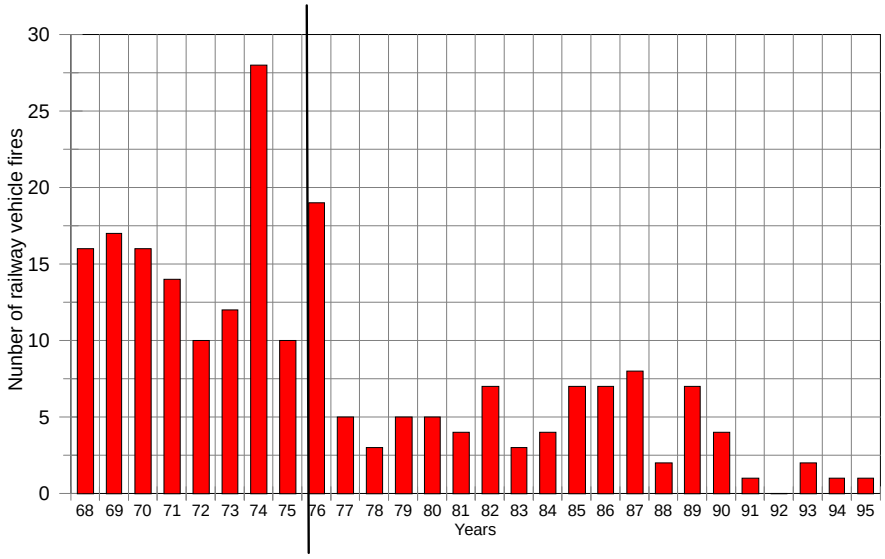
Figure 4: light diffusers requirement for A1 category, matrice n°4

	I 0	I 1	I 2	I 3	I 4	NC
	M 0	M 1	M 2	M 3	M 4	NC
F 0	A	A	**AA**	**AA**	**NA**	**NA**
F 1	A	A	**AA**	**AA**	**NA**	**NA**
F 2	A	A	**AA**	**AA**	**NA**	**NA**
F 3	A	A	**AA**	**NA**	**NA**	**NA**
F 4	A	A	**NA**	**NA**	**NA**	**NA**
F 5	A	**NA**	**NA**	**NA**	**NA**	**NA**

A: acceptable, **NA: non acceptable**, **AA : Acceptable with agreement of user**

The NF F 16-101 regulation is effective since 76 end its achievement clearly shows a decrease of railways vehicle fires.

Figure 5: railway vehicle fires evolution



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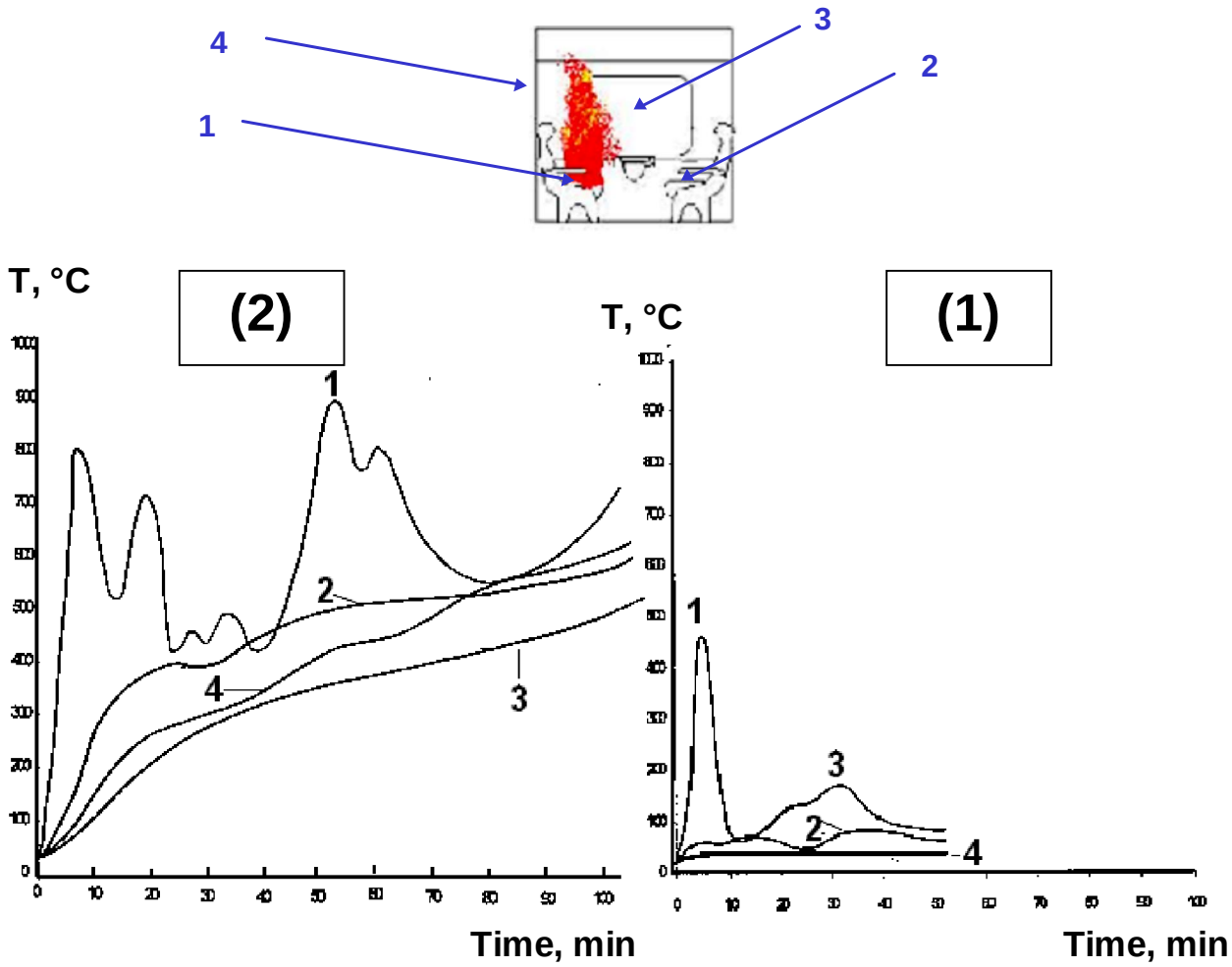
Also note that real scale state has pointed out the strong decrease of fire temperature and so fire spread using material in compliance with the NF F 16-101 requirements

Figure 6: real scale test temperature evolution with (1) and without (2) material complying with the NF F 16-101 requirements



2 DEUTCHLAND

The German Standard for the test procedures and classification of materials and components for the fire behaviour and fire effluents is DIN 5510 Part 2 [98].

The following parameters are defined to classify the fire behaviour of materials and components (both for external parts of car body and for internal materials):

- ✓ Combustibility,
- ✓ Smoke development,
- ✓ Dripping.

Test specimens have to meet end-use requirements.

2.1 Combustibility classification

For the combustibility classification there are five categories defined from S1 (only for small item) and S2 to S5 (all materials and components) and from SF1 to SF3 for floor coverings.

Category S1 is determined by DIN 53438 (part 1-3) [99] ñ Testing of combustible materials; reaction to a flame of a burner; edge and surface flame actionò
The combustibility category from S2 to S5 is obtained using DIN 54837 [100] ñgas burner testò By this test smoke development and dripping will be evaluated too.
The categories SF1 to SF3 for floor coverings are obtained using the test DIN 4102 with evaluation of ñcritical radiation intensityòand smoke emission.

2.2 Combustibility classification

There are two ñsmoke developmentò categories: SR1 and SR2 by evaluating the integral of light attenuation.

2.3 Dripping classification

For ñdrippingò category there are only two levels: ST1 and ST2

The 5510 DIN standard gives in a complete table the minimum requirements of the three parameters for each material and component depending on 4 operation categories.

Table 4: DIN 5510-2 classification

Type of product	Test	Rating
All suitable	Brandschacht DIN 54 837	S2 to S5 SR1, SR2 ST1, ST2
Floor covering	Radiant panel DIN EN ISO 9239-1	SF1 To SF3
Seats	Paper cushion test DIN 54 341	Requirements met
Small pieces	Small burner DIN 53438	S1
Cables	Din EN 50265-2-1 and 50266-2-1	A or B

Table 5: DIN 5510-2 requirements

Component	Fire protection class	Fire rating	Smoke Rating	Flaming droplets rating
Ceiling, end walls and side walls covering	1	S2	No	No
	2 and 4	S5	SR2	ST2
	3	S5	SR2	ST2

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3 ENGLAND

The British classification is in accordance with BS 6853 ñCode of practice for fire precautions in the design and construction of passenger carrying trainsò[104].

This classification regards essentially three vehicles categories:

- ✓ Category Ia and Ib (underground),
- ✓ Category II (surface).

In this Standard each material (except mass loss materials and seat components) is classified by their position on the vehicle.

The most important classification regards all the materials/item with important surface (both interior and exterior of vehicle). For these are provided 3 positions:

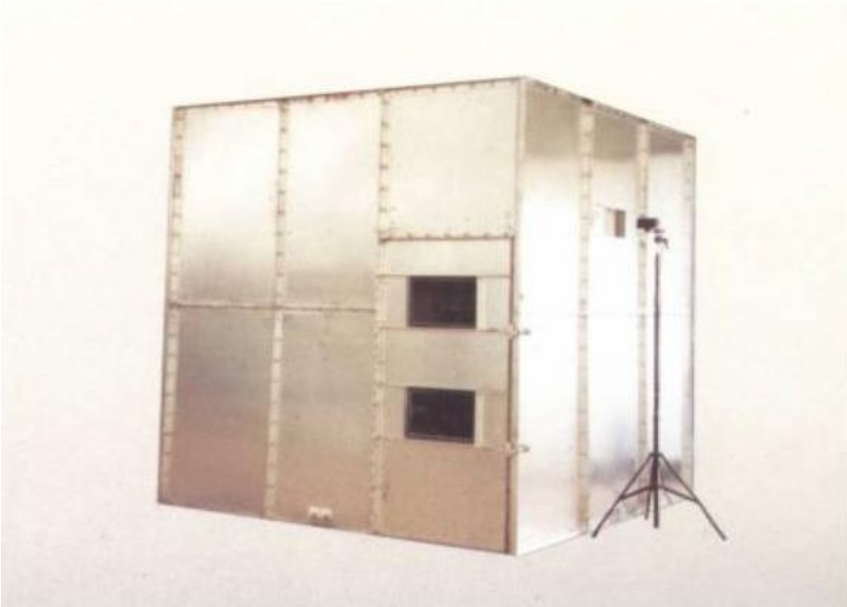
- ✓ Horizontal prone ñceiling-likeò(HP surface),
- ✓ Horizontal supine ñfloor-likeò(HS surface),
- ✓ Vertical ñwall-likeò(V surface).

The fire behaviour parameters evaluated by the British Standard are:

- ✓ Ignitability,
- ✓ Spread of flame,
- ✓ Heat release (using BS476 part6),
- ✓ Smoke opacity,
- ✓ Smoke toxicity.

For the exterior and interior horizontal surfaces the above parameters are evaluated by BS 476-7 [105] (surface spread of flame); smoke density by a 27 meter cube chamber according to Annex D of the standard and smoke toxicity by the test method described in the Annex B of the above Standard.

Figure 7: 27 meters cube chamber



The determination of the weighted summation of toxic gas is obtained by two different methods:

- ✓ The first one is available for the **òminor use materialò** and is based on the mass of the material using NF X 70-100,
- ✓ The second one is available to the **ñsurfaces materials, seat and mattressò** using the cone calorimeter ISO 5659-2 [19] apparatus at 25kW/m².

Table 6: BS 6853 tests

Product	Test
Seating	BS 476-6 Fire propagation box BS 476-7 Surface spread of flame 27 m cube smoke density test ISO 5659-2 Toxic fume emission
Wall and ceilings	BS 476-6 Fire propagation box BS 476-7 Surface spread of flame 27 m cube smoke density test ISO 5659-2 Toxic fume emission
Flooring	ISO 9239-1 Radiant panel test for floorings 27 m cube smoke density test NF X 70-100 Toxic fume emission
Cables	BS 4066 Flammability temperature index on sheath 27 m cube smoke density test NF X 70-100 Toxic fume emission

4 ITALIA

The actual classification used for Italian regulations for the fire behaviour of materials/component is described in the standard UNIFER PrE10.02.977.3 ñGuidelines for fire protection of railway, tramway and guided path vehicles ï Part 3 Evaluation of fire behaviour of materials ï threshold valuesò

Similar to the French Standard, the Italian Standard provides the classification of the material/item by ñreaction to fireò and ñsmokeò (combination of smoke emission and toxicity).

4.1 Reaction to fire

For the parameter ñreaction to fireò (FI parameters) are provided six categories:

- ✓ Class 0 is evaluated by ISO 1182 ñnon combustibility testò,
- ✓ Class1 to Class 5 are determined by the combination the above parameters evaluated with two tests:

-UNI 8456 [108] ñreaction to fire by applying a small flame on both surfacesò and UNI 9174 [109] ñreaction to fire of material attacked by flame with radiant heatingò,
-UNI 8457 [110] ñreaction to fire of material attacked by flame on one surfaceò and UNI 9174 (where the sample is positioned as on the end use e.g. horizontal supine for floor materials, horizontal prone for ceiling materials or vertical for wall materials).

4.2 Smoke parameters

The ñsmokeò parameter is obtained identically to the French Standard, namely from combination of ñsmoke emissionò and ñtoxicity indexò (F value). The first one is evaluated by NF X 10-702 (Smoke density Chamber) and the second one with NF X 70-100 (toxicity test). There are three acceptable classes from F1 to F3.

For electrical materials smoke emission and smoke toxicity are separately evaluated with NF X 10-702 and IEC EN 50267[112] part 1 and 2.
The classification system is done by a ñthreshold valueò for ñreaction to fireò and ñsmokeò for each listed item described in two summary tables in the standard (one for electrical components the second for all other materials/item).

5 USA

The majority of fire safety requirements for US passenger trains consist of material fire performance test criteria designed to prevent the fire or retard its growth and spread. Based on test methods that evaluate fire proper-ties of individual materials. The FRA guidelines [59] and similar requirements for other rail applications form a prescriptive set of design specifications for material selection.

Table 7: Federal Railways Administration 2000 requirements

Index			Test method	Performance criteria
1, 2, 3, 4, 5, 6, 7, 8	Cushions, mattresses		ASTM D-3675	$I_s \leq 25$
			ASTM E-662	Ds (1.5) < 100 Ds (4) <175
1, 2, 3, 6, 7, 8	Fabrics		14CFR, appendix F, Part I, (vertical test)	Flam time < 10 s Burn length<152 cm
			ASTM E-662	Ds(4) < 200
9, 10, 11	Vehicle components	All except cellular foam, floor covering, light transmitting, plastics, and item addressed under categories 1 and 2	ASTM E-162	$I_s \leq 35$
			ASTM E-662	Ds(1.5) < 100, Ds(4) <200
1 and 2		Flexible cellular foams,	ASTM D-3675	$I_s \leq 25$
			ASTM E-662	Ds(1.5) < 100, Ds(4) <175
13 and 14		Floor covering	ASTM E648	CRF>5 kW/m^2
			ASTM E-662	Ds(1.5) < 100, Ds(4) <200
2 and 15		Lights transmitting plastics	ASTM E-162	$I_s \leq 100$
			ASTM E-662	Ds(1.5) < 100, Ds(4) <200
16		Elastomers, 16	ASTM C1166 Average flame propagation, (vertical test)	Pass
17	Wire and cable	Low voltage wire and cable: Wire insulation for control and other low voltage ie less than 100 V AC and150 V DC,	NEMA WC3/ICEA S-19-1981, paragraph 6.19.6; or UL44 and UL 83	Pass
			ASTM E-662	Ds(4) < 200 (flaming) Ds(4) <75 (non flaming)
		Power cable: Wire insulation for control and other high voltage ie more than 100 V AC and150 V DC	ANSI/IEEE Std 383	Pass
			ASTM E-662	Ds(4) < 200 (flaming) Ds(4) <75 (non flaming)
19	Structural components	Flooring 20, Other 21	ASTM E119	Pass

The materials used in locomotive cabs and passenger cars shall be tested according to the methods and meet the performance criteria set forth in the following table and notes:

[1]Materials tested for surface flammability shall not exhibit any flaming running or dripping.

[2]The ASTM E 662-97 maximum test limits for smoke emission (specific optical density) shall be measured in either the flaming or non-flaming mode, utilizing the mode that generates the most smoke.

[3]Testing of a complete seat or mattress assembly (including cushions, fabric layers, upholstery) according to ASTM E 1537-98 with application of pass/fail criteria of California Technical Bulletin 133 shall be permitted in lieu of the test methods prescribed herein, provided the assembly component units remain unchanged or new (replacement) assembly components possess equivalent fire performance properties to the original components tested. A fire hazard analysis must also be conducted that considers the operating environment within which the seat or mattress assemblies will be used in relation to the risk of vandalism, puncture, cutting, or other acts which may expose the individual components of the assemblies.

[4]Testing is performed without upholstery.

[5]The surface flammability and smoke emission characteristics shall be demonstrated to be permanent after dynamic testing according to ASTM D 3574-95, Test I_2 (Dynamic Fatigue Test by the Roller Shear at Constant Force) or Test I_3 (Dynamic Fatigue Test by Constant Force Pounding) both using Procedure B.

[6]The surface flammability and smoke emission characteristics shall be demonstrated to be permanent by washing, if appropriate, according to FED-STD-191A Textile Test Method 5830.

[7]The surface flammability and smoke emission characteristics shall be demonstrated to be permanent by dry-cleaning, if appropriate, according to ASTM D 2724-87.

[8]Materials that cannot be washed or dry-cleaned shall be so labelled and shall meet the applicable performance criteria after being cleaned as recommended by the manufacturer.

[9]As a minimum, combustible component materials required to be tested include seat and mattress frames, wall and ceiling panels, seat and toilet shrouds, tray and other tables, partitions, shelves, windscreens, HVAC ducting, thermal and acoustic insulation, exterior plastic components, and interior and exterior box covers.

[10]Materials used to fabricate miscellaneous, discontinuous small parts (such as knobs, rollers, fasteners, clips, grommets, and small electrical parts) that will not contribute materially to fire growth in end use configuration may be exempted from fire and smoke emission performance requirements, provided that the surface area of any individual small part is not Ó16 square inches (100 cm^2) in end use configuration and an appropriate fire hazard analysis is conducted which addresses the location and quantity of the materials used, and the vulnerability of the materials to ignition and contribution of flame spread.

[11]If the surface area of any individual small part is less than 16 square inches (100 cm^2) in end use configuration, materials used to fabricate such small part shall be tested in accordance with ASTM E 1354-97, unless such small part has been shown not to contribute materially to fire growth following an appropriate fire hazard analysis as specified in Note 10. Materials tested in accordance with ASTM E 1354-97 shall meet the performance criteria of t_{ig}/q_{max} Ò1.5. Testing shall be at 50 kW/m^2 applied heat flux.

[12]Assessment of smoke generation by small miscellaneous, discontinuous parts may be made by utilizing the results from the ASTM E1354-97 test procedure conducted in accordance with Note 11, rather than the ASTM E 662-test procedure, if an appropriate fire hazard analysis is provided which

addresses the location and quantity of the materials used, and the vulnerability of the materials to ignition and contribution of smoke spread.

[13]Carpeting used as a wall or ceiling covering shall be tested as a vehicle component.
[14]Floor covering shall be tested with padding in accordance with ASTM E 648-97, if the padding is used in the actual installation.

[15]For double window glazing, only the interior glazing is required to meet the materials requirements specified herein. (The exterior glazing need not meet these requirements.)

[16]Elastomeric materials used for parts having a surface area Ó16 square inches (100 cm ^{2}) shall be tested in accordance with ASTM C 1166-91. As a minimum, parts required to be tested include window gaskets, door nosing, diaphragms, and roof mats.

[17]Testing shall be conducted in accordance with NEMA WC 3/ICEA S-19-1981, paragraph 6.19.6; or UL 44 for thermosetting wire insulation and UL 83 for thermoplastic wire insulation.

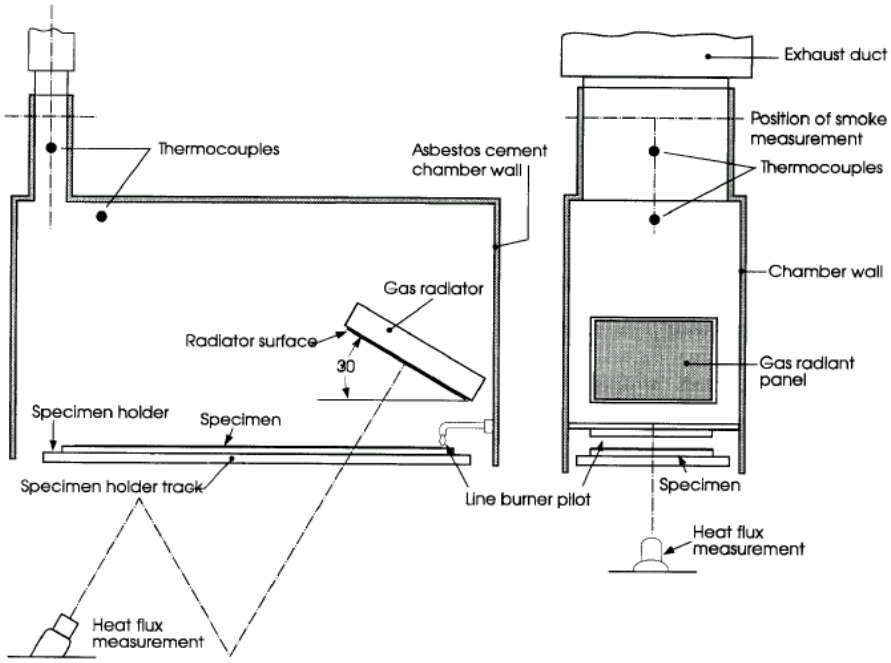
[18]Testing shall be conducted in accordance with ANSI/IEEE Standard 383-1974, section 2.5, with the additional requirement that circuit integrity shall continue for 5 minutes after the start of the test.

[19]Penetrations (ducts, etc.) shall be designed to prevent fire and smoke from entering a vehicle, and representative penetrations shall be included as part of test assemblies.

[20]Structural-flooring assemblies shall meet the performance criteria during a nominal test period as determined by the railroad. The nominal test period must be twice the maximum expected time period under normal circumstances for a vehicle to stop completely and safely from its maximum operating speed, plus the time necessary to evacuate all the vehicle's occupants to a safe area. The nominal test period must not be less than 15 minutes. Only one specimen need be tested. A proportional reduction may be made in the dimensions of the specimen, provided the specimen represents a true test of the ability of the structural flooring assembly to perform as a barrier against under-vehicle fires. The fire resistance period required shall be consistent with the safe evacuation of a full load of passengers from the vehicle under worst-case conditions.

[21]Portions of the vehicle body (including equipment carrying portions of a vehicle's roof but not including floors) which separate major ignition sources, energy sources, or sources of fuel-load from vehicle interiors, shall have sufficient fire endurance as determined by a fire hazard analysis acceptable to the railroad which addresses the location and quantity of the materials used, as well as vulnerability of the materials to ignition, flame spread, and smoke generation.

Figure 8: THE ASTM E-648 Flooring radiant panel [36]



The Flooring Radiant Panel test or ñStandard Test Method for Critical Radiant Flux of Floor Covering Systems Using a Radiant Heat Energy Source -ASTM E 648-ñ exposes a specimen placed horizontally to a radiant source that varies across a 1 m length from a maximum of 11 kW/m^2 down to 1 kW/m^2. After ignition by a small line burner at the high radiant flux end, the distance at which the burning floor material self extinguishes is determined. This point defines the critical radiant flux (CRF) necessary to support continued flame spread. The higher the CRF, the better is [he fire performance of the floor covering.

Also note that Federal requirements do not contain any settlement in term of smoke toxicity. In order to implement these requirements in term of safety increase, some train makers have set up internal standard which measure the potential smoke toxicity.

For example, Bombardier has developed a SMP 800-C test method based on BSS 7239 standard (Boeing Safety Standard, same methodology for aircraft standards). The BSS 7239 described the use of Drager Tube for the measurement of toxic gases. This technique is known to be grossly inaccurate. As a result, Bombardier has developed an absorptive sampling procedure in which 6 litres of gas are sampled, starting at 4 minutes, over a 15 minutes period. The resulting levels which are report, therefore, the cumulated concentrations over the 15 minutes period.

Table 8: SMP 800-C toxicity smoke requirement

Gas	Symbol	Critical Concentration (ppm)
Carbon monoxide	CO	3500
Carboen Dioxyde	CO2	90000
Oxides of Nitrogen	NO + NO2 (Nox)	100
Sulfur dioxide	SO2	100
Hydrogen Chloride	HCl	500
Hydrogen fluoride	HF	100
Hydrogen Bromide	HBr	100
Hydrogen cyanide	HCN	100

6 0verview of future regulation in Europe

The European Commission has funded a 3-year research programme in 1997 to assist the work of CEN/TC256/WG1 and CENELEC/TC9X/WG3 in drafting a Part 2 (Requirements for the fire behaviour of materials and components) for a 7-part European Standard prEN 45545 ñFire protection on railway vehiclesò[56]

The major aim of the project [122] is to develop the most representative and comprehensive test methods giving results significant enough to classify the constituent products of railway vehicles taking into account the acceptable risks for users, the vehicle design, the shape and use of the products, the functional equipment, the ventilation system and all relevant combinations of these items.

Table 9: overview of the test selected for the screening of materials

1	ISO 5658-2	Lateral flame spread test with radiant panel source
2	ISO 5660-1	Cone calorimeter test for ignition time and heat release rate.
3	ISO 5659-2	Single chamber smoke test (cumulative conditions)
4	NF X 70-100 (UITP E6)	Static furnace test for fire effluents
5	DIN 53436	Moving furnace test for fire effluents
6	EN ISO 9239-1	Radiant panel test for horizontal flame spread on floorings
7	EN 1021-4	Ignitability test for seats using burner equivalent to 100g paper
8	NT FIRE 032	Furniture Calorimeter Tests. Upholstered furniture : Burning behaviour ï Full Scale Test
9	IEC 60695-2-11	Glow wire test
10	IEC 60695-2-4/2	Ignitability and flammability test with 500W flame source
11	EN ISO 11925-2	Small flame test
12	IEC 60695-2-30	Ignitability and flammability test with 1kW flame source.
13	EN 50399	Cable Calorimeter Tests

The FIRESTARR classification divides the materials into three important categories:

- ✓ Structural materials,
- ✓ Furniture materials,
- ✓ Electrical materials.

For each category (and in some cases for each type of component), it will provide the test method to evaluate all the parameters of the fire behaviour. Afterwards on the basis of the determined values it will classify the material/component in three categories:

- ✓ A for high performance product,
- ✓ B for medium performance product,
- ✓ C for low performance product.

The EN 45545 deployment processes has evolved and to know more about the issues, feel free to download

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- CREPIM Newsletter 2 Fr
- CREPIM Newsleter 3 En

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TABLES LIST

FIGURES LIST

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